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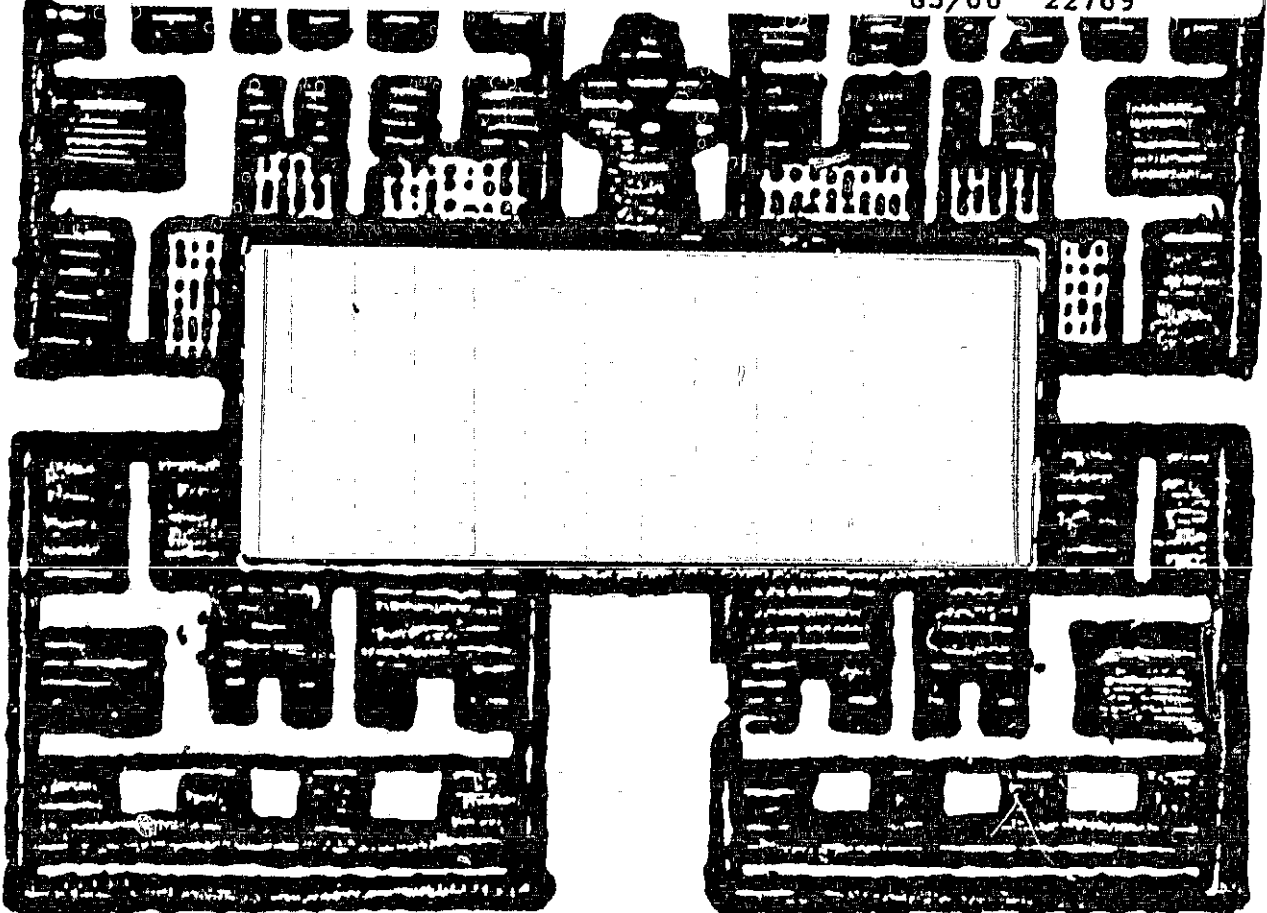
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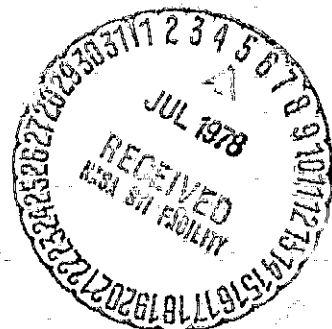
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QUADRANGLE / STANFORD UNIVERSITY

PLANNING & MANAGEMENT

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INFRASTRUCTURE DYNAMICS:

A SELECTED BIBLIOGRAPHY

by

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Preface

This bibliography was prepared as part of an ongoing effort in the Infrastructure Planning and Management Program at Stanford, which is directed toward the exploration of the utility of dynamic simulation techniques in the forecasting, planning and evaluation of infrastructure systems. The term "infrastructure" is used to denote the set of life-support and public service systems which is necessary for the development of growth of human settlements.

While no claim is made that this bibliography is comprehensive and all-encompassing, it does include some basic references in the field of dynamic simulation, as well as a number of relevant applications in the area of infrastructure planning. The intent is to enable the student or researcher to quickly identify such applications to the extent necessary for initiating further work in the field. The relatively small number of applications is a reflection of the recent interest of planners in the transfer of dynamic systems techniques to their own field. It should be emphasized, however, that the utility and effectiveness of these techniques in planning has by no means been established. This remains to be one of the major thrusts of the research effort at Stanford.

The bibliography was prepared by both a manual search of the literature, and a computerized search of sources available through the Stanford Libraries Computer Search Service. Some of the annotations are those provided by the authors, while others have been specifically prepared for this bibliography.

1. THE SYSTEM DYNAMICS METHOD

1.1 Modelling Approach

Allen W. "On Accuracy, Precision, and The Real World: Some Thoughts on System Dynamics as a Policy Tool." Report No. p-5540, Rand Corporation: Santa Monica, California.

This paper is a critique of the "World Model" designed by Forrester and Meadows. Forrester and Meadows' view of what constitutes a valid and useful model, and what role quantification plays in the generation of an accurate model are examined. Conclusions are that a great deal of more scientific inquiry is required before models of this kind can be considered reliable aids to policy making.

Barney, G.O. "System Dynamics, and the Analysis of Social Policy." Professional Paper No. 89, Center for Naval Analysis: Washington, D.C., 1972.

There has been considerable debate as to the substance of System Dynamics and the applicability of this method to social policy analysis. This paper presents an evaluation of System Dynamics and its relevance for policy analysis.

DeGreene, K.B. "Technological Change and Manpower Resources: A Systems Perspective." Human Factors, Vol. 17, No. 1, 1975.

The article synthesizes theories and findings from behavioral and social sciences within the framework of systems theory. The need for advances in theory and methodology are argued. The elements of systems theory are sketched, and the value of the System Dynamics approach to modelling and computer simulation is emphasized.

Kornbluh, M., and Little, D. "The Nature of a Computer Simulation Model." Technological Forecasting and Social Change, Vol. 9, No. 1/2, 1976, pp. 3-26.

An overview of computer simulation and the systems approach. This paper discusses the key concepts, applications, shortcomings and characteristics of a number of mathematical modeling and computer simulation techniques, including those of System Dynamics.

Schroeder III, W.W. "System Dynamics: A Unique Tool for Analyzing Data Deficient Social Systems." I.E.E.E., Transaction on Systems, Man and Cybernetics, Vol. SMC-2, No. 2, 1972.

The paper argues that much of the limitations in the applicability of system analysis techniques in social problems are related to the lack of concrete data with which to define and validate models. It is concluded that this barrier has been greatly reduced by the advent of System Dynamics.

1.2 The Technique

Burns, J.R., and Malone, D.W. "Computational Techniques for the Analysis of System Dynamics Models of Social Systems." Socio-Economic Planning Sciences, Vol. 8, 1974, pp. 215-223.

The computational techniques of sensitivity analysis are extended to System Dynamics models, and are shown to enhance the understanding of model behavior, and to contribute to considerations of model validity. Optimization analyses are shown to contribute to model utility and policy formulation.

Cole, H.S.D., and Curnow, R.C. "Backcasting With The World Dynamics Models." Nature (Great Britain), Vol. 243, May, 1973.

The paper discusses whether a system dynamics model can meaningfully be run backwards in time.

Mohapatra, P.K. "Some Generalized Results on Exponential Delays." Transaction of the International Association of Mathematics and Computers, Simulation (Belgium), Vol. 18, No. 4, 1976, pp. 217-221.

Exponential delays are widely used in literature on System Dynamics, due primarily to their simplicity of form and their adequacy to fit the usual degree of knowledge about the actual system to be represented. An attempt is made in this paper to arrive at certain useful results through the generalized methods for the analysis of transients of these delays generated by changes in their inflow rate.

Sahin, K. E. "Simulating Discrete Systems with System Dynamics Using Multiple Simulation Intervals." Bulletin of the Operations Research Society of America, Vol. 23, Supplement 1, 1975.

The paper shows how some systems are best modelled through simultaneous use of multiple simulation intervals in the same model, and by relating these intervals to the "natural" accumulation intervals of the real systems. An application example is provided.

Young, F.W., et al., "Parameter Identification and Dynamic Models of Socioeconomic Phenomena." I.E.E.E., Transaction on Systems, Man and Cybernetics, Vol. SMC-2, No. 4, 1972.

A methodology is presented for developing socioeconomic models of the System Dynamics type. A means of including socioeconomic experts into the modelling process is suggested, and it is emphasized that such models are not scientific models, but assemblages of expert opinion. An illustration is provided, using a model of the Lake Tahoe basin in Northern California.

1.3 Model Testing and Validating

Peterson, D.W. "Statistical Tools for System Dynamics." In Ervik and Randers (Ed.), The System Dynamics Method, Proceedings of the International Conference on System Dynamics, 1976.

This paper describes practical, automatic tools to aid both the builder and the evaluator of a System Dynamics model. The tools relate the model to available data, and are based on full information and maximum likelihood via optimal filtering. They operate correctly in an environment of noisy data, missing points, unmeasured variables, and unknown inputs.

Peterson, D.W. "Hypothesis, Estimation and Validation of Dynamic Social Models." Ph.D. Thesis, M.I.T., 1975.

This thesis establishes a unified set of techniques for the estimation and validation of nonlinear, dynamic, time-varying models, with special reference to models and data typical of the social sciences.

This paper considers the general problem of validation in System Dynamics modeling, and surveys the tests available for building confidence in System Dynamics models. The paper concentrates more on what is known than on what is not known about validation. The breadth of tests presented also demonstrates the variety of channels available for building confidence in System Dynamics models.

1.4 Extensions and Related Techniques

1.4.1 Optimization

Burns, J.R., and Malone, D.W. "Optimization Techniques Applied To The Forrester Model of the World." I.E.E.E., Transaction on Systems, Man and Cybernetics, Vol. SMC-4, No. 2, March 1974, pp. 164-171.

Two methods for optimizing System Dynamics models are presented. Applicability of the models is demonstrated using the Forrester World Model as the vehicle.

Lunderstaedt, R. "Transportation Systems With Optimal Parameters." Problems in Control Information Theory, Vol. 5, No. 2, 1976, pp. 109-116.

Optimization problems with ordinary differential equations and transportation equations as System Dynamics are considered using the calculus of variations in the formulation of Hamilton. The theoretical results are explained further in an example.

Tavalage, J. "Control Theory Applied to System Dynamics Simulations." Proceedings of the 1973 Summer Computer Conference, 1973, pp. 849-851.

Simulation models for social, economic, and ecological systems have been developed with increasing frequency in recent years. A significant portion of these models have a dynamic nature; they are primarily oriented toward the study of system behavior as it changes with time. There are several special purpose simulation languages which accommodate such models including DYNAMO, FORDYN, CSMP, and MIMIC. To this point, the DYNAMO language has found the most application, and is therefore the focal point of this paper.

1.4.2 Forecasting and Cross Impact Analysis

Blackman, A.W. "The Use of Dynamic Modelling for Conditional Forecasts of Resource Allocation Policies," Technological Forecasting and Social Change, Vol. 6, 1974, pp. 191-208.

A System Dynamics model is described which was developed to simulate resource allocation policies in an industrial research laboratory and was used to investigate the effects of various levels of internal support in a selected area of research on the projected amount of external government support to be received in future time periods. The model was validated by simulating a historical resource allocation policy and comparing computed results with actual government support received during 1963 - 1972. The computed results agreed well with historical data. The validated model was then used to investigate different strategies for the allocation of internal discretionary research funds and to produce conditional forecasts of the extent of future external research support.

Blackman, A.W. "New Venture Planning: The Role of Technological Forecasting," Technological Forecasting and Social Change, Vol. 5, No. 1, 1973.

A system for the analysis and planning of new venture, which provides a structure for the application of mathematical procedures, was developed. The system is based on a synthesis of various analytical techniques: technological forecasting; decision analysis; and System Dynamics.

Blackman, A.W. "Forecasting Through Dynamic Modeling," Technological Forecasting and Social Change, Vol. 3, 1972.

System Dynamics forecasting is used in the simulation of a representative industrial research laboratory to forecast the effect on future operations of matching an exploratory forecast of the laboratory's output to an exogenous goal schedule set by normative forecasts of future requirements. The laboratory operating policies which were found to produce stable growth patterns in response to normative growth goals were different from those which would have been intuitively stated.

Bloom, M.F. "Time-Dependent Event Cross-Impact Analysis: Results From a New Model." Technological Forecasting and Social Change, Vol. 10, 1977, p. 201.

This time-dependent event cross-impact model involves four stages. In the first stage an undistributed world view, prior to new information being obtained, is projected for a set of events to occur with specified probability densities over an indefinite time horizon. In the second stage, the estimator fills in the cells of a cross-impact matrix with qualitative estimates of the strength and direction of the impacts. Qualitative cross-impacts are converted to a quantitative form by the analyst conducting the exercise. In the third stage, it is assumed that new information becomes known to the estimator causing him to project anew the time-dependent probabilities of the events in the set. In the fourth and final stage, an event cross-impact simulation model is constructed in System Dynamics and run to produce new probability densities of the event set. These densities take into account both the cross-impacts between events and the effect of the newly obtained information. The possible results include both shifts of the most likely time of occurrence and changes in the cumulative probability of the events. The chief usefulness of the model is that it provides a method of foreshortening the time required by decision-makers to take into account the effect of new information on the probability of events occurring over a time period.

Bloom, M.F. "Deterministic Trend Cross-Impact Forecasting." Technological Forecasting and Social Change, Vol. 8, No.1, 1975.

This work is part of a larger effort to develop a computer simulation model to forecast the behavior of the population-economy-welfare system of Israel for the 1974-1980 period. In the process of achieving this goal, a new technique was developed for the purpose of analyzing past trends and projecting them into the future. Using this technique, it is now possible to produce alternative future histories of social trends that are simultaneously extrapolated from the past and are interacting with each other. The methodology used in the model includes a combination of three well known forecasting techniques: trend extrapolation; cross-impact analysis; and System Dynamics simulation.

Dajani, Jarit, S. and Gilbert, Gorman, "Delphic Prediction and Cross Impact Simulation." Journal of the Urban Planning and Development Division, ASCE, Vol. 101, No. UPI, Proc. Paper 11316, May 1975, pp. 49-59.

The writers review two techniques that are potentially useful tools in urban and regional planning. These techniques are the Delphi method for obtaining subjective predictions about a changing future through a panel of experts and Cross-Impact Simulation for combining a number of discrete subjective forecasts with a number of similar related forecasts to produce alternative descriptions of the future. The potential of this class of techniques for planners and engineers who are involved in managing the future is pointed out. The use of the techniques is specifically relevant to situations where subjective judgments have to be made about complex interrelated events. The paper presents mathematical examples of the utilization of these two complimentary methods.

Sharif, M. Nawaz, and Kabir, Chowdhury, "System Dynamics Modeling for Forecasting Multilevel Technological Substitution." Technological Forecasting and Social Change, Vol. 9, 1976.

The existing mathematical models of trend extrapolation for forecasting technological substitution deal primarily with cases where a new product or technology replaces the old one over a period of time in at least some portion of the market. However, in the presence of rapid technological change, one can think of many examples where a particular product or technology is replacing an older one, while at the same time being replaced by a newer one -- a multilevel substitution process. Moreover, any forecast made at a given point in time needs to be revised as varying circumstances influence the elements of the forecast. This paper presents a systematic methodology (i) for forecasting multilevel technological substitution, and (ii) for incorporating various forms of time dependent parameters in the existing trend extrapolation models. The methodology is based on the "System Dynamics" technique and combines the exploratory and the normative approaches to technological forecasting. In addition to the forecasting of market share, the models can also predict the annual size of the market of each of the competing technologies or products.

2. MODELS OF INFRASTRUCTURE SYSTEMS

1 Energy

Dyrd, J., Jr., Schrader, L.A., Haynes, R.D. "An Application of Systems Dynamic Modelling to Energy Systems Planning." Bulletin of the Operations Research Society of America, Vol. 19, Sup. 2, B229, 1971.

The Systems Dynamics concepts developed by Jay Forrester have been examined in a study of an energy systems model. The relevance of this approach is examined with particular emphasis on the manner in which systems dynamics concepts can be used in an area of activity where decisions are fragmented and uncoordinated. The system dynamics model also gives insight into the problems which need to be examined by a national energy commission.

Meadows, Dennis L., Ford, F. Andrew, Naill, Roger, "Critical Post-1985 Energy Policy Issues." Thayer School of Engineering, Hanover, N.H., Dartmouth System Dynamics Group, Federal Energy Administration, Washington, D.C., Report No. DSD-35.

This report identifies eight interdisciplinary issues requiring the most careful analysis because of their fundamental importance to energy policy. It also identifies six issues which demonstrate a variety of justifications for formulating energy policy in the context of post-1985 considerations. A taxonomy of energy issues is developed and used to identify the extent to which nine policy areas receive too little or too much attention.

Meadows, D.L., et al., "The Transition to Coal." Dynamics Group, Dartmouth College, Annual Report No. 2, 1974.

The basic energy problem facing the U.S. and other industrialized nations is not to secure independence from foreign energy suppliers, rather to negotiate an orderly transition from primary reliance on fossil oil and gas resources to predominant use of energy sources not tied to finite fuel reserves. This report describes the major energy problem currently facing the United States, and proposes a long-term energy strategy based on increased U.S. coal production. Major environmental, capital, and labor constraints affecting coal demand and production are discussed. A model is fully described.

Naill, R.F. "System Dynamics Energy-Model." Transactions of the American Nuclear Society, Vol. 24, No. V19, P22, 1976.

In this report a System Dynamics model of discovery of U.S. natural gas is presented as an example of the discovery process of natural resources.

Rhan, R. Joel. "Long-Term Dynamic Model of Energy Availability and Use in the U.S." Pittsburgh Conference on Modeling and Simulation, 1973, pp. 69-73.

This paper describes the assumptions and preliminary results of a systematic modeling effort to provide alternative long-term projections of availability and use of energy in the U.S. The System Dynamics methodology is used in creating a multi-loop feedback structure to determine these projections by continuous simulation in the DYNAMO language.

Teele, J.D. "The Policy Effects Analysis Method: A System Dynamics Simulation Study of the Defense Fuel Supply System." Report No. p-5129, The Rand Corporation: Santa Monica, California, 1973.

This study analyses the issues regarding the usage, supply and management of jet fuels and aviation gasolines as they affect military operations.

2.2 The Environment

Anderson, J.H. "System Simulation to Test Environmental Policy: The Eutrophication of Lakes." Environmental Letter, Vol. 3, No. 3, 1972.

A simple model of nutrient cycling and oxygen consumption is presented using System Dynamics as the modelling and simulation technique. The failure of solutions to remove nutrient elements in some form is explained using systems concepts.

Chapman, L.D., et al., "Environmental Dynamics of Toxic Releases and their Transport to Man." Proceedings of the Pittsburgh Conference on Modelling and Simulation, 1975.

A System Dynamics model is presented which explores the long term distribution of transuranics released to the environment.

Jacobsen, J. Jay, "A Dynamic Analysis of the Environmental and Social Impacts of Coal Development in the Eastern Powder River Basin of Wyoming, 1960-2010." Report No DSD-32, Thayer School of Engineering, Dartmouth System Dynamics Group, 1975.

As a result of the expressed national goal of reducing oil and gas imports, the U.S. coal industry is trying to increase coal production, in particular by expanding the production of strip-mined coal in western states. In an effort to understand and help resolve the conflict arising from this increase in production, a dynamic regional coal-development model of the Eastern Powder River Basin was constructed. This report presents the model, and uses the model to evaluate several alternative development scenarios for the studied region. The report specifically examines large-scale gasification and electrical-generation development.

Peppard, L.E. "Computer Simulation Models for Ecological Systems." Proceedings of the 1972 International Conference on Cybernetics and Society, I.E.E.E., 1972.

This paper presents some applications of non-linear feedback modelling techniques to the study of animal population dynamics. A state-variable version of Forrester's System Dynamics technique is used to obtain models for the growth of a single species limited by food supply, competition between two species, and a predator-prey relationship. Model behavior is compared with that observed of real species.

2.3 Water Resources

Griegg, Neil S., Bryson, Maurice C. "Interactive Simulation for Water System Dynamics." ASCE Journal Urban Planning and Development Division, Vol. 101, May 1975, pp. 77-92.

The urban simulation modeling techniques demonstrated by Forrester can also be applied to urban water problems, particularly those concerned with the economics of supply-storage-use problems. An example of a rate policy simulation study for Fort Collins, Colorado is presented. The flexibility of the approach is emphasized but the need for valid data, as in all simulation studies, is not understated. The modeling approach presented emphasizes an interactive simulation, written in BASIC language and run on an office size minicomputer, available to

practically any engineering office. Although this case was restricted to an urban water supply system, the methodology should be valid for many other engineering-economic problems as well.

Pugh, Alexander L., III, Rabe, Frank T. "System Simulation to Assess Environmental Impacts of Water Resources Development." Summer Computer Simulation Conference, Montreal, Canada, 1973. Available from Simulation Council, Inc., La Jolla, California.

Federal requirements for evaluating the environmental consequences of public projects have created an increasing awareness of the inadequacies of existing evaluative techniques. Authors are developing a comprehensive model for assessing environmental impacts of water resource projects which addresses several major methodological weaknesses. The model, based on system dynamics, is composed of six sectors: demography; industry; water; land use; recreation; and biology. It is intended to be a supplementary tool for the preparation of environmental impact statements.

Richardson, J.M. "A Model of Institutional Behavior As A Component of of Regional Water Quality Management." Case Western Reserve University, Proceedings of the Fourth Annual Pittsburgh Conference on Modeling and Simulation, Vol. 4, April 1973.

This paper presents one of the components of a larger project which focuses on the problem of long term cultural eutrophication. The overall objective of the model described is to stimulate the behavior of the institutions involved with the assessment of policy options which are available at the federal level.

2.4 Transportation and Telecommunications

Beal, J.C., Peppard, L.E. "Multidisciplinary Modelling of Telecommunications in a Developing Region." Proceedings of the National Telecommunications Conference, 1975.

The modelling techniques known as Systems Dynamics have been employed to investigate their potential use as planning tools in the study of telecommunications in a developing region of Canada. A regional model of northwest Ontario has been constructed and extensively tested. In

addition, models of two small communities within the region have been studied. The work is being performed by a multidisciplinary team from six disciplines and the modelling concept has been found to be very useful as a central focus for their efforts. Some discussion is included on the use of these models and the question of their validation.

Dajani, Jarir S. "Assessing the Future of Air Freight." Working Paper, Program in Infrastructure Planning and Management, Department of Civil Engineering, Stanford University, Stanford Ca., November, 1977.

This report briefly discusses the role of air cargo in the current transportation system in the United States. It then addresses the question of assessing the future role of this mode of transportation, and recommends the use of continuous-time recursive systems modeling for the simulation of different components of the air freight system, and for the development of alternative future scenarios which may result from different policy actions. A basic conceptual framework for conducting such a dynamic simulation is presented within the context of the air freight industry. Some research needs are identified and recommended for further research. The paper also discusses the benefits, limitations, pitfalls, and problems usually associated with large-scale systems models, and emphasizes the benefits of the exercise as a learning tool which will enable the user to expand his understanding of the freight movement system and the interactions between alternative assumptions and system behavior patterns.

Flory, J.E., Hunter, P.T., Meredith, A.P. "Effect of Nation Transportation/ Energy Policy on Regional Transportation Phenomena." Simulation, 1977.

Most regional transportation modeling studies have focused on microlevel phenomena operating within the region. In contrast, the model presented in this paper utilizes a hierarchical causality approach to examine the impact of higher-level (i.e. national) policies on macro-level regional transportation characteristics. Specifically, the individual and joint effects of national trends in gasoline price, transit funding, and fuel economy of automobiles are examined with respect to their influence on two Sacramento regional variables: transit usage and transportation fuel consumption. The authors conclude that given the uncertain future of causal forces that are beyond the

region's control (e.g., gasoline price), a macrolevel analysis may be a more judicious use of limited transportation planning resources.

Kane, J. "A Primer for a New Cross-Impact Language -- KSIM." Technological Forecasting and Social Change, Vol. 4, 1972, pp. 129-142.

A new methodology/language has been developed which serves to make available the workings of cross-impact analysis to a much larger audience in that no technical sophistication is required to become expressive in the new language. Unlike the procedures developed by Gordon, et al these methods stress the structural dynamics of the system, the geometry of the linkages rather than refining arithmetic estimates of future probabilities. However, while qualitatively and subjectively oriented, these procedures can be easily expanded to any degree of precision, providing the data and mechanisms are sufficiently well known. The key feature of this approach is that it allows one to work with data of any level -- from subjective estimates to highly precise physical measurements -- and the computer has the character of logical projections of basic hypothesis rather than dogmatic imperatives which is the nature of much of present social, economic, technological, and ecological modelling.

Mohler, R.R. "Transportation Systems Dynamics." Proceedings of the International Conference on Cybernetics and Society, Boston, Mass., November, 1973, pp. 100-101.

The role of variable structures and adaptive control in transportation planning and in traffic control is analyzed here. A state-wide skeletal model is formulated from the complex interactions of transportation and socioeconomic processes. Control of this complicated system is studied by means of land-use planning, taxation and legislation. Also, transportation as a control mechanism for socioeconomic development is introduced. The need for adaptive traffic control, as it affects air pollution and transportation quality in general, is studied.

Scheller, P. "Possibilities and Limits of Simulation by the Forrester Systems Dynamics Statement as a Method for Complex Systems Investigations Exemplified by a Typical Aerospace Transport." Technische University, Berlin (West Germany), Inst. fuer Luft- und Raumfahrt, Report No. IRL-16-1974, 1974.

The System Dynamics method was applied on the simulation of the management structure of the German airline company, Deutsche Lufthansa. The desirability of introducing a new type of aircraft (Airbus) into an existing fleet was investigated. Possibilities and limitations of the simulation method in connection with DYNAMO, the problem oriented simulation language used, are discussed. Advantages of the system include great flexibility, good possibility of documentation, possibility of very easy learning. However, DYNAMO does not allow interval interventions and it does not dispose of enough macros for representing all of the world's (system) discrete events.

Sussman, J.M. "A Systems Model of the U.S. Railroad Industry." Bulletin of the Operation Research Society of America, Vol. 23, Supplement 1, B/133-4, 1975.

For over forty years a cycle of decreased market share, lowered profitability, deferred maintenance, and poor service leading to further market share decreases has been in effect. This research models the rail industry and quality and cost of service provided. The model is calibrated on historical data and will be used to evaluate the effectiveness of various industry and government policies.

Taylor, A.J. "System Dynamics In Shipping." Operations Research Quarterly (Great Britain), Vol. 27, No. 1, 1976, pp. 41-56.

A system which exhibits time-varying fluctuations in measures which describe its state and which comprises inter-dependent feedback loops is likely to be amenable to the modelling methods of system dynamics. The shipping industry is analysed from this point of view with the aim of identifying its dynamic characteristics and their causal mechanisms. Examples are given of observed dynamic behavior within and between trade sectors.

U.S. Department of Transportation, "Alternative Future Scenarios For the National Aviation System." Prepared by The Futures Group and Urban Systems Research and Engineering. Report 174-72-01 (Revised), Federal Aviation Administration, 1975.

This study was directed at: 1) Depicting a plausible range of future socioeconomic scenarios in the year 2000, which are likely to effect future demand for air transportation, and ways in which that demand will be met; 2) Describing alternative evolutions of the U.S. Aviation System which are likely to emerge from such conditions; 3) Designing and documenting analytic techniques for developing those scenarios so that the F.A.A. (or other appropriate agencies) would be able to duplicate the results, and update them as conditions continue to change.

Vogt, W.G., Mickle, M.H. "Dynamic Simulation of Public Transit with Application to Bangkok Bus Operations." Modeling and Simulation, Vol. 5, 1974, pp. 721-726.

A general urban public transit model has been developed using system dynamics; computer simulation runs using Bangkok data are presented. Various policies for achieving a balanced transportation system for Bangkok are tested. Sensitivity analyses indicate that many of the parametric values assumed are insensitive to policy changes so that much of the data being collected in contemporary studies is of little use.

Wakeland, W. "QSIM2: A Low-Budget Heuristic Approach to Modeling and Forecasting." Technological Forecasting and Social Change, Vol. 9, 1976, pp. 213-229.

This paper contains a description of a simple mathematical framework and modeling process which can be used to study a large class of socio-techno-natural systems. Models may be designed using intuitive notions or data to help specify the variables, parameters and interrelationships, which with the aid of a computer program, can be used to forecast system behavior under various assumptions. Two example models are described.

2.5 Urban and Regional Planning

Arañil, J., Bueno, J.M., "System Dynamics and Civil Planning." Dyna (Spain), Vol. 51, No. 7-8, July-August, 1976, pp. 275-281.

The advent of the computer changed the whole outlook of engineers through the introduction of ideas on dynamic systems, system design, the principles of modern control theory, the systematic study of the concept of feedback and the application of these ideas to traditional engineering problems and problems of engineering management. By constructing mathematical models to simulate the problem requiring study, models can include factors not readily grasped by the human decision maker; these ideas are now being applied to socio-economic problems. This article discusses the methodology of system dynamics, the symbols and the computer language used, and as an example deals with the application of this method to the problem of siting a large new industry in a relatively undeveloped area.

Bascom, S.E. et al. "Secondary Impacts of Transportation and Wastewater Investments: Research Results." Prepared by the Environmental Impact Center for the U.S. Environmental Protection Agency, Report No. EPA-600/5-75-013, July 1975.

This work concentrates on the interactions among land use, highways, sewers, and housing. Applications are made to four urban areas: Denver, Minneapolis - St. Paul, Boston, and Washington.

Cordey-Hayes, M.C. "Dynamic Frameworks for Spatial Models." Socio Economic Planning Sciences, Vol. 6, 1972, pp. 365-385.

Emphasizes the importance of integrating dynamic simulation modelling with a serious program of experimental research devoted to the formal understanding of urban growth processes.

Cossetto, S., DeJulio, S., LaBella, A. "A Dynamic Simulation Model of the Residential Sector of Rome Province." Report No. R74-20, University Rome, Italy, July 1974.

Attempts to build an integrated model of a congested and still expanding urban area. The methodology of systems dynamics has been used. The main contribution of this paper is a general methodology for evaluating the model sensitivity with respect to parameter variations.

Dickinson, Thomas E., Schwartz, Seymour, I. "Socioeconomic Impacts of Rural Land Use Control: A Simulation Study." Journal of Environmental Systems, Vol. 4, No. 4, 1974, pp. 279-297.

The conversion of land for urban use is of concern not only at the urban fringe, but also in the rural hinterlands, where large tracts have been subdivided and sold to urban residents for second homes or for speculation. To examine the consequences of policies for controlling rural land conversion, a systems dynamics model of land use and the economy of a rural California county was developed and simulated. The additional effects of reduced fuel availability on the tourist economy of the county are examined and the potential dangers and benefits of applying simulation methods to the policy making process are discussed.

Drew, D.R., Lal Chand Wadhwa, H. Paul, et al. "Simulation of the Bicol River Basin Development, Philippines." Modeling and Simulation, Vol. 6, 1976, pp. 1187-1191.

A system dynamics model of the developmental planning of the six-province Bicol region in the Philippines is explained. The model, which consists of about 1650 variables, is being used to simulate development alternatives in this economically depressed region. Emphasis is placed on the use of the model rather than the methodology. Specifically, it is shown how the user can evaluate the consequences of alternative strategies, policies, and programs for promoting economic and social development.

Krendel, Ezra S. "Social Indicators and Urban Systems Dynamics." Socio-Economic Planning Sciences, Vol. 5, 1971, pp. 387-393.

The urban resident's perception of the discrepancies between his aspirations and his achievements may be conceived of as a rapidly responding indicator of urban life quality. This social indicator, which is a multidimensional construct, can be estimated from freely generated citizen complaints, questions, comments, behavior, action, and so forth. A scheme is presented in which the perceived discrepancies serve as an error signal to an urban system which attempts to reduce such errors. Complaints and questions were followed in time through several components of the urban system and selected process dynamics were estimated so that changes in configuration and procedures for improved municipal performance could become more apparent.

Mariariello, Joseph A. "Dynamic Benefit Cost Analysis: Policy Evaluation in a Dynamic Urban Simulation Model." Socio-Economic Planning Sciences, Vol. 9, 1975, pp. 147-168.

Many social problems have characteristics that make them difficult to analyze accurately by static methods. They are complex, which means that causes and effects are manifold and separated in time. When static benefit-cost models are used to evaluate proposed programs affecting these problem areas, they may lead us to policy choices that are essentially incorrect -- choices that may actually make matters worse.

The simulation methodology has been applied to a typical urban (i.e. central city) area for purposes of illustrating a comparative-dynamic procedure for benefit-cost analysis. Application of this methodology has produced insights into some fundamental issues of benefit-cost analysis, particularly the procedures for selecting a social discount rate, incorporating uncertainty, and establishing boundary conditions for the modeling effort. These insights have been generalized for application to the appraisal of other complex systems.

Murphy, J.H., Vogt, W.G., Mickel, M.H. "Metropolitan Dynamics - A Model of Urban, Suburban, and Rural Interactions." Modeling and Simulation, Vol. 5, 1974, pp. 33-38.

A System Dynamics model of a nation, which contains both rural and urban areas is described. In the model, an urban area consists of a central city and surrounding suburb, each represented by a modified version of J. W. Forrester's Urban Dynamics Model. Population flows are conserved within the nation; immigration into the nation takes place exogenously. Therefore, the availability of people migrating into the nation or moving from the rural sector limits urban immigration.

Picardi, A.C. "Practical and Ethical Issues of Development in Traditional Societies: Insight from a System Dynamics Study in Pastoral West Africa." Simulation (U.S.A.), Vol. 26, No. 1, 1976.

The results of a system dynamics model are presented and analysed, and the conclusion is drawn that not all the desired objectives for developing the region can be attained simultaneously. The fact that practical

tradeoffs exist leads to consideration of some ethical issues which may enter into the choice of alternative development policies. The principal data source for this study is the sahel and subdesert of Niger, north of Tahoula, where herdsmen practice traditional animal husbandry -- seeking pastures in the north during the rainy season and descending south toward the agricultural zones in the dry season. A set of seven desirable long-term objectives is defined and policies to achieve them are simulated. The simulation results indicate definite tradeoffs among the desired objectives. The existence of mutually exclusive attainable objectives leads to a consideration of the ethical issues involved in the choice of alternate development policies.

Richardson, John M., Jr. and Pelsoci, T. "Regulation and Control of Urban Environments: A Multi-Level Approach." Systems Research Center, Case Western Reserve University, Second Annual Pittsburgh Conference on Modelling and Simulation, March 1971.

An organization-environment model, combining the Urban Dynamics and Hierarchical Multi-level Systems approaches is proposed as a basis for a "science of the artificial" focusing on urban problems. In order to combine the two approaches, a multi-echelon model of a political system must be modified to include infimal, supremal and overall performan criteria.

Schuck, Stephen K. "Migration, Income and Public Policy in a Three-Region Agricultural Economy: A Simulation Model for Peru." Stanford Ph.D. Dissertation, June, 1977.

The purpose of this research is to construct a simulation model of the Peruvian agricultural economy that can facilitate the study of the influence of migration on regional economic development programs; and, through its use, to develop a recommendation for the general orientation of Peruvian rural development policy. The resulting model simulates Peru's three geographic regions, each with a rural and an urban sector. Each rural sector is further divided into production activities representing the principal types of agricultural practice (selected, as appropriate for each region from irrigated crops, rain-fed crops, and pasture). Each production activity, including urban production, has its own capital stock, and each rural

production activity has a corresponding land stock. Labor is assumed to be relatively (but not perfectly) mobile between rural sectors and between regions through explicit migrations. Capital accumulation, land development, commodity prices, minimum wages, reinvestment rates, and transport and social infrastructure investments are assumed to be elements of economic policy. Data from the 1960-1970 decade are used to calibrate the model.

White, K. Preston, Bajani, Jari S., and Wright, Donald. "System Dynamics Approach to Urban Planning." Journal of the Urban Planning and Development Division, ASCE, Vol. 100, No. UP1, Proc. Paper 80388, March 1974, pp. 43-56.

Forrester employs System Dynamics technique for modeling complex, multiloop, feedback systems -- a technique which he claims bridges the gap between engineering and the social sciences -- to transform his theory of the economic and demographic growth and decay of a city into a computer model. In this paper both the modeling technique and its specific application to an urban area are considered. Forrester uses the urban dynamics model to describe the "natural" evolution of a city and to test the effects of various public policies on the urban system. Simulation results and the disconcerting policy recommendation Forrester extracts from them are considered. It is concluded that although the urban dynamics model is not itself an accurate representation of a city, the potential of systems analysis in social simulation is great.

3. Selected Major References

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